Donghun Kim

Energy Technologies Area, Building Tech. & Urban Systems Division, Lawrence Berkeley National Lab.
90R3147, 1 Cyclotron Road, Berkeley, CA 94720, USA, donghunkim@lbl.gov, +1 510-486-4022

EDUCATION

Ph.D., 2015, Mechanical Engineering, Purdue University, U.S.
M.S., 2010, Mechanical Engineering, KAIST, S.Korea
B.S., 2008, Mechanical Engineering, Pusan National University, S.Korea (valedictorian)

RESEARCH AREA

Transient system modeling, machine learning, system identification, optimization and control for HVAC, smart building and grid systems

EXPERIENCE

Computational Research Scientist, Building Technology & Urban Systems Division, Lawrence Berkeley National Laboratory Jan/2020-present

- Next generation heat pump load flexibility (EPIC HP-Flex project) June/2020-present
- Optimal design and control for combined heat pump and phase change material system (Hybrid HVAC with thermal energy storage research and demonstration project) Jan/2020-present
- Development and campus-level demonstration of hierarchical and distributed model predictive controls for optimal operation of district cooling systems (CERC project) March/2019-present
- Integrated sensor and control system for occupants' thermal comfort control (Hot, Cold or Just Right Project) March/2020-present
- Fuzzy logic-based condensing cooling coil modeling (Modelica Buildings Library) 2019-present

Research Assistant Professor, School of Mechanical Engineering, Purdue University July/2016-Feb/2019

- Development, evaluation and demonstration of model predictive control for a chiller plant with ice storage tanks Jan/2018-Jan/2019
- Development of a scalable approach for electrical demand management using the building as energy storage Jan/2018-Jan/2019
- Fast building energy simulation tool for optimal design and control analysis Jan/2018-Jan/2019
- Extending the Unit Coordinator to handle economizers and heat pumping equipment Jan/2018-Jan/2019
- Laboratory evaluation of extremum seeking controller for variable speed DX unit 2017-2018
- Dynamic system modeling and control of an affordable Organic Rankine Cycle 2016-2017
- Development of fast dynamic simulation tool for Vapor Compression Cycles Jan/2019-
- Extending Roof-top unit (RTU) Coordinator for load shifting and enhanced peak load reduction 2017-2018

Postdoc Researcher, Purdue University Aug/2015-Jun/2016

- Automation and demonstration of MPC in small/medium-sized commercial buildings

- Development of an integrated MPC for convenience stores with refrigerated cases (collaborated with Virginia tech and Oak Ridge National Laboratory)
- Development of computationally efficient modeling approach for evaporator performance under frost conditions

Research Assistant, Purdue University Jan/2011-Aug/2015

- Development of disturbance modeling approach for building control
- Development/demonstration of a practical control algorithm for multiple roof-top unit (RTU) coordination (collaborated with Oak Ridge National Laboratory)
- Development of a reduced-order CFD coupled modeling approach for evaluation of a control algorithms for small/medium size building (collaborated with Interdisciplinary Center for Applied Mathematics, Virginia tech)
- Development of a model order reduction method for general multi-zone buildings for building control analysis and optimization
- Assessment of Modelica buildings library (collaborated with Simulation Research Group, Lawrence Berkeley National Lab)

Commissioned Researcher, Korea Institute of Energy Research Apr/2010-Dec/2010

- System modeling of a 1kW solid-oxide fuel cell (SOFC) and experimental demonstration
- CFD analysis of electro-chemically reacting flows and thermal stress analysis for a SOFC unit cell and experimental validation (10×10 planar type)
- Numerical analysis and experiment of a liquid fuel combustion

Research Assistant, KAIST, S.Korea Feb/2008-Feb/2010

- Study on *Rapid Distortion Theory* of turbulence flows
- Computational models of pressure strain correlation in turbulent homogeneous shear flows
- Low *Renolds* number modification of C_μ in standard $\kappa - \epsilon$ turbulent model
- CFD analysis of *Ranque-Hilsch* vortex tube
- Fluid structure interaction analysis (wind effect on a bridge)

Rolls-Royce, Canada Oct/2006 - Aug/2007

- Engine air system modeling and analysis of a *Rolls-Royce* low cost dual fuel combustion system
- Sizing and analyzing a fuel distribution system
- Analysis of transient auto-ignition impacts
- Analysis of valve water hammer impacts

RESEARCH GRANT

- Next Generation Heat Pump Load Flexibility, Co-PI, GFO-19-301,Sponsored by California Energy Commission, $ 3.0 M, Jan. 2020
- Development of a Fast Dynamic Simulation Tool for Vapor Compression Cycles, Sponsored by LG and Johnson Controls Inc. via the Center for High Performance Buildings (CHPB) at Purdue, $60 k, Oct. 2018
- Extending the Unit Coordinator to Handle Economizers and Heat Pumping Equipment, Sponsored by Johnson Controls Inc. via CHPB, $60 k, Nov. 2017

- Development of a Scalable Approach for Electrical Demand Management using the Building as Energy Storage, Sponsored by Southern California Edison and Duke Energy via CHPB, $60 k, Nov. 2017
- Fast Building Energy Simulation Tool for Optimal Design and Control Analysis, Sponsored by Kawneer via CHPB, $60 k, Nov. 2017
- Development, Evaluation and Demonstration of Model Predictive Control for an Ice Storage System - Phase 1, Sponsored by Ingersoll Rand, $76 k, Oct. 2017
- Extending the RTU Coordinator for Load Shifting and Enhanced Peak Load Reduction, Sponsored by Johnson Controls Inc. and mCloud Corp. $50 k, Nov. 2016
- Automation and Demonstration of an RTU Coordinator in Small Commercial Buildings, Sponsored by Johnson Controls Inc. and mCloud Corp., $70 k, Nov. 2015

AWARDS AND ACHIEVEMENTS

- Best paper, student best paper competition, 2^{nd} International High Performance Buildings Conference, U.S. 2012
- ASHRAE graduate student grant-in-aid award, U.S. 2012
- Scholarship, Kwanjeong educational foundation, S.Korea 2009
- Valedictorian and presidential gold medal for the highest GPA, Pusan National University, S.Korea 2008
- Selected as *Next Generation Researcher*, Korean Research Foundation, S.Korea 2006
- National engineering scholarship, Korea Science and Engineering Foundation, S.Korea 2003-2006

PROFESSIONAL SOCIETIES

- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
  - Subcommittee Chair, TC 7.5 Smart Building Systems
  - Corresponding Member, TC 1.13 Optimization
  - Corresponding Member, TC 1.4 Control Theory and Application
- American Society of Mechanical Engineers (ASME) - Technical Committee, Energy Systems (ESTC)
- Institute of Electrical and Electronics Engineers (IEEE)- member

SERVICE

Book Chapter Contributor

- ASHRAE Handbook, "Chapter 42: Supervisory Control Strategies and Optimization", *American Society of Heating, Refrigerating and Air-Conditioning Engineers*, 2018.
- ASHRAE Handbook, "Chapter 63: Smart Building Systems", *American Society of Heating, Refrigerating and Air-Conditioning Engineers*, 2020.

Conference and Workshop Activities

- Organizer : Seminar
  - Grid-Interactive Efficient Buildings: Introduction and Demonstration Projects, *ASHRAE 2020 Virtual Conference*, June/2020
- Organizing Committee : Workshop
  - Model Predictive Control in Buildings: Today and Tomorrow, International Workshop, 2020 (deferred due to COVID-19)
- Organizing Committee : Conferences
  - Purdue Herrick Conferences, 2018
- Organizing Committee : Conference Sessions
  - Control & Energy Management of Building Systems, *American Control Conference*, 2017-2019
- Conference Session Chair
  - Advanced Equipment Controls II, *International Refrigeration and Air Conditioning Conference*, 2018
  - Building and Facility Automation II, *American Control Conference*, 2018
  - Control & Energy Management of Building Systems, *American Control Conference*, 2017
  - Transient System Modeling, *International Refrigeration and Air Conditioning Conference*, 2017
  - Air Conditioning Equipment Assessments, *High Performance Buildings Purdue Conference*, 2016
- Technical Committee Subcommittee Chair
  - Buildings Operations and Dynamics, TC 7.5 Smart Building Systems, ASHRAE, 2020-present

Reviewer

Journal Publications Reviewed

- Applied Energy: (11/2016)
- Energy and Buildings: (06/2016, 04/2017, 05/2017, 11/2017, 03/2017, 02/2018, 09/2018)
- IEEE Transactions on Industrial Informatics: (02/2016)
- IEEE Transactions on Control Systems Technology (11/2016, 09/2016, 04/2017, 11/2017)
- Journal of Building Performance Simulation: (11/2015, 02/2016, 06/2016, 03/2017, 02/2018, 03/2018, 04/2018, 05/2018)
- HVAC& R Research: (01/2015)
- Simulation, Transactions of the Society for Modeling and Simulation International: (09/2016)
- Journal of Dynamic Systems, Measurement and Control-ASME: (10/2018)

Conference Publications Reviewed

- 2019 American Control Conference (2)
- 2018 17th International Refrigeration and Air Conditioning Conference (11)

- 2018 IEEE Conference on Decision and Control (3)
- 2018 IEEE Conference on Control Technology and Applications (1)
- 2018 American Control Conference (1)
- 2017 IEEE Conference on Control Technology and Applications (1)
- 2017 Building Simulation 2017 (7)
- 2017 American Control Conference (2)
- 2016 Refrigeration and Air Conditioning Purdue Conference (3)
- 2016 High Performance Buildings Purdue Conference (2)
- 2016 American Control Conference (1)

Technical Advisory Committee

- NREL (National Renewable Energy Laboratory) project, The Vision for the Commercial Building Integration Laboratory in the ESIF, 2018-2019
- LBNL (Lawrence Berkeley National Laboratory) project, BOPTEST (Building Optimization Performance Tests), 2019-present

EDUCATIONAL ACTIVITIES

- Guest Lecturer (March/2018): Building Mechanical and Electrical System Design (CE 41400), Purdue University. Created a course module (4 class period) to teach air conditioner and heat pump systems.
- Graduate Student Advising (Aug/2017-present)
  - Kairui Hao, (2020). Comparing the Economic Performance of Ice Storage and Batteries for Buildings with On-site PV Through Model Predictive Control (Master's thesis), *Purdue University*
  - Jiacheng Ma, (2019). Reduced Order Modeling for Vapor Compression System via Proper Orthogonal Decomposition (Master's thesis), *Purdue University*

TECHNICAL PRESENTATIONS AND INVITED TALKS

- Kim, D. (2020). First Experimental Results of Optimal Load Shifting for Small and Medium Sized Commercial Buildings: Impact on Energy Efficiency, *ASHRAE 2020 Virtual Conference*
- Kim, D. (2019). Energy Savings Potential of Model Predictive Control for Supervising Multiple Rooftop Unit Economizers, *Intelligent Building Operations Workshop, University of Colorado Boulder, Colorado*
- Kim, D. (2019). Evaluation of the Krylov Subspace Method for Model-Order Reduction to Enable Faster Building Simulations for Large-Scale Buildings, *Intelligent Building Operations Workshop, University of Colorado Boulder, Colorado*
- Hao, K., Kim, D. & Braun, J.E. (2019). Comparing the Economic Performance of Ice storage and Batteries for Buildings with On-site PV, *Intelligent Building Operations Workshop, University of Colorado Boulder, Colorado*
- Kim, D. (2019). Enabling Algorithm for Grid-Interactive Efficient Small & Medium Sized Commercial Buildings, *Korea Institute of Energy Research*
- Kim, D. (2019). Model Order Reduction Methods for Faster Building Simulations, *Pusan National University, S.Korea*
- Kim, D. (2019). System Identification for Building Thermal Systems under the Presence of Unmeasured Disturbances in Closed Loop Operation: Theoretical Analysis and Application, *Chonnam University, S.Korea*

- Kim, D. (2018). A Low-Cost MPC Solution for Small-Medium Sized Commercial Buildings, *Lawrence Berkeley National Laboratory*
- Kim, D. & Braun, J.E. (2018). Low-Cost MPC for Load Shaping in Small Commercial Buildings, *Intelligent Building Operations Workshop*
- Braun, J.E. & Kim, D. (2018). Model Predictive Control of Multiple Rooftop Air Conditioners in Small Commercial Buildings, *ASHRAE Winter Conference*

PUBLICATION

Journal Papers

1. Kim, D., Ma, J., Braun, J.E. & Groll, E.A. (2020). Fuzzy Modeling Approach for Transient Vapor Compression and Expansion Cycle Simulation, *International Journal of Refrigeration*, doi:10.1016/j.ijrefrig.2020.10.025
2. Drgoňa, J., Arroyo, J., Figueroa, I.C., Blum, D., Arendt, K., Kim, D., Ollé, E.P., Oravec, J., Wetter, M., Vrabie, D.L. & Helsen, L. (2020). All you need to know about model predictive control for buildings, *Annual Reviews in Control*, doi:10.1016/j.arcontrol.2020.09.001
3. Kim, D. & Braun, J.E. (2020). Model Predictive Control for Supervising Multiple Rooftop Unit Economizers to Fully Leverage Free Cooling Energy Resource, *Applied Energy,* 275, 115324. doi:0.1016/j.apenergy.2020.115324
4. Kim, D., Bae, Y., Yun, S. & Braun, J.E. (2020). A Methodology for Generating Reduced-Order Models for Large-Scale Buildings using the Krylov Subspace Method, *Journal of Building Performance Simulation,* 13(4), 419-429, doi:10.1080/19401493.2020.1752309
5. Kim, D. Braun, J.E. & Ramaraj, S. (2018). Computationally Efficient Modeling Strategy for Evaporator Performance under Frost Conditions, *International Journal of Refrigeration*, 96, 88-99. doi.org/10.1016/j.ijrefrig.2018.09.004
6. Kim, D. & Braun, J.E. (2018). Development, Implementation and Performance of a Model Predictive Controller for Packaged Air Conditioners in Small and Medium-sized Commercial Building Applications, *Energy and Buildings*, 178, 49-60, doi:10.1016/j.enbuild.2018.08.019
7. Kim, D., Cai, J., Braun, J.E. & Ariyur, K.B. (2018). System Identification for Building Thermal Systems under the Presence of Unmeasured Disturbances in Closed Loop Operation: Theoretical Analysis and Application, Energy and Buildings, *Energy and Buildings*, 167, 359-369, doi:10.1016/j.enbuild.2017.12.007.
8. Kim, D., Ziviani, D., Braun, J.E. & Groll, E.A. (2017). A Moving Boundary Modeling Approach for Heat Exchangers with Binary Mixtures, *Energy Procedia*, 129, 466-473, ISSN 1876-6102, https://doi.org/10.1016/j.egypro.2017.09.161.
9. Ziviani, D., Kim, D., Subramanian, S.N., Braun, J.E. & Groll, E.A. (2017). Feasibility Study of ICE Bottoming ORC with Water/EG Mixture as Working Fluid, *Energy Procedia*, 128, 762-769, ISSN 1876-6102, doi:10.1016/j.egypro.2017.09.226
10. Kim, D., Cai, J., Ariyur, K.B. & Braun, J.E. (2016). System identification for building thermal systems under the presence of unmeasured disturbances in closed loop operation: Lumped disturbance modeling approach. *Building and Environment*, 107, 169-180. doi:10.1016/j.buildenv.2016.07.007
11. Ayed, S. B., Kim, D., Borggaard, J. & Cliff, E. M. (2016). Optimal control of indoor-air cooling in buildings using a reduced order model. *Energy*, 116, 1191-1204. doi:10.1016/j.energy.2016.10.022

12. Cai, J., Kim, D., R. Jaramillo, Braun, J.E. & Hu, J. (2016). A general multi-agent control approach for building energy system optimization. *Energy and Buildings*, 127, 337-351. doi:10.1016/j.enbuild.2016.05.040
13. Cai, J., Braun, J.E., Kim, D. & Hu, J. (2016). General approaches for determining the savings potential of optimal control for cooling in commercial buildings having both energy and demand charges. *Science and Technology for the Built Environment*, 22(6), 733-750. doi:10.1080/23744731.2016.1197716
14. Kim, D., Braun, J.E., Cai, J. & Fugate, D.L. (2015). Development and Experimental Demonstration of a Plug-And-Play Multiple RTU Coordination Control Algorithm for Small/Medium Commercial Buildings, *Energy and Buildings*, 107, 279-293. doi:10.1016/j.enbuild.2015.08.025
15. Kim, D., Braun, J.E., Cliff, E. & Borggaard, J. (2015). Development, Validation and Application of a Coupled Reduced-Order CFD Model For Building Control Applications. *Building and Environment*, 93(2), 97-111. doi:10.1016/j.buildenv.2015.05.032
16. Putta, V.,Kim, D., Cai, J. & Hu, J. & Braun, J.E. (2015). Dynamic Programming Based Approaches to Optimal Rooftop Unit Coordination, *Science and Technology for the Built Environment*. 21(6), 752-760. doi: 10.1080/23744731.2015.1059153
17. Kim, D. & Braun, J.E. (2015). A General Approach for Generating Reduced-Order Models for Large Multi-Zone Buildings. *Journal of Building Performance Simulation*. 8(6), 435–448. doi:10.1080/19401493.2014.977952

Conference Papers

1. Ayed, S. B., Kim, D., Borggaard, J. & Cliff, E. (2019). Uncertainties on Cooling Energy Based on Computational Indoor Air Modeling in Sports Facilities. *ASHRAE Transactions*, 125(2), 14+.
2. Kim, D., Bae, Y., Braun, J.E. & Horton, T. (2018). A Tool for Generating Reduced-Order Models from Building Energy Simulation Input Files to Enable Optimal Design and Control Analysis, *2018 International High Performance Buildings Conference*, ID3614
3. Ma, J., Kim, D. & Braun, J.E. (2018). Development of a Fast Method for Retrieving Thermodynamic Properties to Accelerate Transient Vapor Compression Cycle Simulation, *2018 International Refrigeration and Air Conditioning Conference*, ID2620
4. Kim, D. & Braun, J.E. (2018). Hierarchical Model Predictive Control Approach for Optimal Demand Response for Small/Medium-Sized Commercial Buildings, *2018 American Control Conference*
5. Kim, D., Cai, J. & Braun, J.E. (2017). Identification Approach to Alleviate Effects of Unmeasured Heat Gains for MIMO Building Thermal Systems, *The 2017 American Control Conference*,50-55, doi: 10.23919/ACC.2017.7962929
6. Ziviani, D., Kim, D., Subramanian, S.N., Braun, J.E., Groll, E.A. (2017). Affordable Rankine Cycle (ARC) for Heavy-Duty Truck Waste Heat Recovery, *International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, ECOS2017*
7. Cai, J., Jhang, H., Kim, D., Braun, J.E. & Hu, J. (2017). Convex Optimization-Based Control of Sustainable Communities with On-Site Photovoltaic (PV) and

Batteries, 1007-1012, *2017 IEEE Conference on Control Technology and Applications*, doi:10.1109/CCTA.2017.8062591

8. Kim, D. & Braun, J.E. (2017). Field Performance of a Model Predictive Controller for Coordinating Multiple Rooftop Units, *2017 ASHRAE Annual Conference*
9. Kim, D. & Braun, J.E. (2016). Integrated Control of RTUs and Refrigeration Equipment in Convenience Stores. *2016 High Performance Buildings Conference*, ID3642, 1-8.
10. Kim, D., Ramaraj, S. & Braun, J. E. (2016). Computationally Efficient Modeling Approach for Evaporator Performance under Frost Conditions. 16^{th} International Refrigeration and Air Conditioning Conference, ID2643, 1-9.
11. Cai, J., Braun, J. E., Kim, D. & Hu, J. (2016). A Multi-Agent Control Based Demand Response Strategy for Multi-Zone Buildings. *2016 American Control Conference (ACC)*, 2365-2372. doi:10.1109/ACC.2016.7525271
12. Cai, J., Kim, D., Braun, J. E. & Hu, J. (2016). Optimizing zone temperature setpoint excitation to minimize training data for data-driven dynamic building models. *2016 American Control Conference (ACC)*, 1478-1484. doi: 10.1109/ACC.2016.7525125
13. Kim, D., Braun, J. E., Cai, J. & Hu, J. (2015). Development of a plug-and-play multiple RTU coordination control algorithm for small/medium commercial buildings. *2015 American Control Conference (ACC), IEEE*, 1659-1664. doi:10.1109/ACC.2015.7170971
14. Kim, D., Braun, J.E., Cliff, E., Borggard, J. & Hu, J. (2015), Performance Evaluation of an RTU Coordination Controller using a Reduced-Order CFD Coupled Model, *ASHRAE Winter Conference*
15. V. Putta, Kim, D., J.Cai, Hu, J. & Braun, J.E. (2015), A Switched Dynamic Programming Approach towards Optimal Control of Multiple Rooftop Units, *2015 American Control Conference (ACC), IEEE*, 281-287. doi:10.1109/ACC.2015.7170749
16. Cai, J., Kim, D., V. Putta, Braun, J.E. and Hu, J. (2015) Multi-Agent Control for Centralized Air Conditioning Systems Serving Multi-Zone Buildings. *American Control Conference (ACC2015), IEEE*, 986-993, doi:10.1109/ACC.2015.7170862
17. Kim, D., Cai, J. & Braun, J.E. (2014). Comparisons of Model Structure and Identification Methods for Multiple-RTU coordination, *Proceedings of the 9^{th} International Conference on System Simulation in Buildings - SSB 2014*
18. Kim, D., Cliff, E. & Braun, J.E. & Borggaard, J. (2014). Development of Control Benefit Evaluation Tool for Small Commercial Buildings, *ASHRAE/IBPSA-USA Building Simulation Conference Atlanta, GA*, 64-71
19. Kim, D., Witmer, L., Brownson, J.R.S. & Braun, J.E. (2014). Impact of Solar Irradiance Data on MPC Performance of Multi-Zone Buildings. *Proceedings of the 3rd International High Performance Building Conference*
20. V. Putta, Kim, D., Cai, J., Hu, J. & Braun, J.E. (2014) Distributed Model Predictive Control for Building HVAC systems: A Case Study. *Proceedings of the 3rd International High Performance Buildings Conference*
21. Kim, D., Zuo W., Braun, J.E. & Wetter, M. (2013). Comparisons of Building System Modeling Approaches for Control System Design, *Proceedings of BS2013: 13th Conference of International Building Performance Simulation Association, Chambéry, France*, 3267-3274

22. V. Putta, G. Zhu, Kim, D., Hu, J. & Braun, J.E. (2013). Comparative Evaluation of Model Predictive Control Strategies for a Building HVAC system. *American Control Conference (ACC2013), IEEE*, 3455-3460. doi: 10.1109/ACC.2013.6580365
23. Kim, D. & Braun, J.E. (2012). Reduced-Order Building Modeling for Application to Model-Based Predictive Control. *IBPSA-USA Journal*, 5(1), 554-561.
24. Kim, D. & Braun, J.E. (2012). Model-based Predictive Control for Buildings with Decoupling and Reduced-order Modeling. *Proceedings of the 2nd International High Performance Building Conference*
25. Kim, D., Braun, J.E., Borggaard, J., Cliff, E. & Gugercin, S. (2012). Coupled CFD Building Envelope Model for the Purdue Living Lab. *Proceedings of the 2nd International High Performance Building Conference*
26. V. Putta, G. Zhu, Kim, D., Hu, J. & Braun, J.E. (2012) A Distributed Approach to Efficient Model Predictive Control of Building HVAC Systems. *Proceedings of the 2nd International High Performance Building Conference*